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Development of the Cortex in Chara.

Illustrated by a Series of American Species.

By T. F. ALLEN.

(Plates XV–XXII.)

A classification of the species of *Chara* based upon a correct and thorough knowledge of their morphological characteristics was first attempted by the late Prof. A. Braun, who so arranged the genera and species of the whole order Characeae, that we are able to trace a gradual development from the simplest dioecious *Nitella*, with unicellular stems and leaves, to the most completely developed *Chara* (*C. fragilis*, Desv.). The formation of "nodes" and a complete development of the node-bract and fruit-bearing leaf may be already seen in the simplest *Chara*; but the genus is still further elevated by the growth of a cortical series of cells, which may be traced from the rudimentary cells of the leaf-node to a perfect evolution.

The development of "stipules" (traces of which begin to appear in the most highly organized *Nitella*) has been used by Prof. Braun to mark the three general divisions of the genus *Chara*, and the character of the cortication serves to mark sub-divisions. Both stipular and cortical cells spring from the nodal cells, and a consideration of their character must be preceded by an inquiry into the nature of a node.

The stem of a characeous plant grows through the formation of cells, by a process of sub-division of the apical growing cell. In Plate XV, Fig. 1*a*, *a* represents the growing apical cell; *n*, a cell which has itself sub-divided and is destined to be the node; and *i*, an internodal cell which does does not sub-divide, but which is destined to elongate indefinitely. The next figure (Fig. 1*b*) illustrates a developed stem, in which the inter-nodal cells *i*, *i* have extended, while the nodal cell *n* has sub-divided, but has not elongated.

From these nodal cells develop, in various ways, all organs—leaf, bract and new shoots; antheridia and sporangia; stipules and cortex.

Since, in this paper, we have to deal with the development of the cortex of the stem only, we may consider first a node of the stem with a basilar node of a leaf.

"A primary nodal-cell of the stem divides, soon after its origin, into two secondary cells by means of a vertical septum through its diameter; in each of these half-cells a semi-circle of peripheral cells forms by a farther eccentric, vertical fissation in such manner that a new fissation occurs alternately on one or the other side of the semicircle. Both semi-circles begin on the same side of the node, progress toward each other, and, when at last they close together, form a complete circle of cells enclosing the two central cells, which, as remnants of the original halving-cell, form the nodal cells in the strictest sense. The peripheral cells are the mother-cells of just so many leaves. The number of these cells, and of leaves in a verticil, amounts in most *Nitellae* regularly to six (very seldom five) and in *Chara* mostly to eight or ten, or even to fourteen or more. The leaves of successive verticils alternate with each other; for the halving-septum of each succeeding node forms an angle with that of the preceding, equal to a half interval of a verticil, so the position of the first leaf of each successive vertical deviates a half interval from that of the first leaf of the preceding verticil. In this way a definite precession is established; the first leaves of the verticils forming a spiral with small divergence ($\frac{1}{12}$, $\frac{1}{14}$, $\frac{1}{16}$, etc.). This spiral is always to the left (downward, T. F. A.); and in this direction, with the increasing tension of the internodes, a more or less noticeable torsion of the stem takes place, most distinctly seen in corticated species; in the naked species marked by the oblique course of the chlorophyll granules and indifferentiated striae (indifferenz-streifen) as well as by the direction of the circulation." (A. Braun.)

Fig. 1*c*, of the same plate, represents a stem-node of *Chara coronata*, as seen from above, without the leaves. Each of the peripheral cells develops a leaf, as follows: the cell divides into two unequal portions by a horizontal septum, the lower and smaller segment remains in the node, while the upper divides into a "globular complexity" of cells, protrudes from the node and forms the basilar node of the leaf. This node consists of central and peripheral cells. The peripheral cells divide parallel to the surface of the node-disk, giving rise to superposed marginal cells; *the lower marginal cells give rise to the cortex-cells of the stem*; and the upper develop usually somewhat on either side of the lower and give origin to the stipules. Usually there are two stipules at the base of each leaf, one on either side, but in *Ch. ceratophylla* there is a third stipule developed from a cell arising between the other two. In *Ch. coronata* one of the lateral stipular cells fails to develop and but one stipule is seen, so that the stipules seem to alternate with the leaves. In *Lychnothamnus Wallrothii* the stipular cell remains directly in the centre, and the stipule is exactly opposite the leaf, no cortex being developed. *Chara stelligera*, possessing neither stipules nor cortex, exhibits at the base of the leaf three insignificant cells, protruding slightly. In *Nitella* and *Tolypella* we find no trace of cortical or stipular cells, though now and then accessory, simple, leaf-like formations remind one of stipules. In *N. hyalina* these are numerous, arising from the base of the leaves in pairs, externally or even internally.

The cortex-cells, arising from the basilar node of the leaf, behave in a manner quite similar to the primary cells of the stem. They consist of alternate, elongated and nodal cells; the former elongating as the stem elongates, the latter not elongating, but forming a node which develops a wart or spine and lateral cells.

1.—Some species of *Chara* never develop these cortex-tubes, and the stems remain naked, like those of *Chara coronata*, Ziz.

2.—Some species develop a simple cortex-tube, which is so small that it does not join the one from the next leaf, as *Chara inconnexa*, Allen.

3.—Some cortex-nodes develop spines but no secondary tubes; the primary tubes join and completely encircle the stem; *e. g.*, *Ch. crinita*.

4.—Some cortex-tubes show a partial development of secondary tubes, as in *Chara evoluta*, Allen.

5.—Some cortex-tubes develop *one* secondary cell only, which becomes as long as the primary cell, but smaller in size, as in *Chara excelsa*, Allen (also *Chara intermedia*, A. Br., *Ch. contraria*, A. Br.). (Section Tylacanthae.)

6.—Some develop only one lateral cortex-cell, which becomes larger than the primary cell and partially covers it, so that the primary cell seems to lie in a valley (Section Aulacanthae); for example, *Ch. foetida*, A. Br.

7.—Some cortex-cells develop perfectly one lateral cell and imperfectly another, as, for example, *Ch. aspera*.

8.—Some cortex-cells develop perfectly both lateral cells, so that three complete series of cells arise from each leaf, as in *Ch. fragilis* (also in *Ch. gymnopus*, A. Br.).

In Plate XV the figures correspond to the divisions given above. In *Chara aspera* the greatest variability may be observed (Fig. 7 from true *aspera*, Canada, and 7*a* from var. *Macounii*). In Fig. 7 the secondary cells meet obliquely, while in 7*a* one of the secondary cells extends past the other, so that a section of the stem at this point would show more than double the number of cortical tubes as compared with the leaves of the verticil. Fig. 7*b* was taken from a form of *Ch. aspera*(?) from Fort Pond, Long Island; unlike those of the typical *Ch. aspera*, the secondary cells join with square and not obliqe ends, and these cells never or rarely overlap, as in true *aspera*; but the irregularity of the cortex is produced by the partial and irregular development of secondary cells from the opposite side of the node of the primary cell.

I have been unable to find subterranean bulblets on this plant, and a thorough examination may show affinities rather with *Ch. Krausii* (whose secondary cortex-cells join rectangularly) than with *Ch. aspera*. In Fig. 8 is represented a typical triplostichous cortex in which cells develop from both sides of the node to the primary cell and extend upward and downward to join cells from neighboring nodes. In Fig. 8*a* is represented an anomaly, sometimes noticed, in which, by reason of an unusual extension of some cells, the cortex becomes hyper-triplostichous. In Fig. 8*a*, *x*, *x* represent the primary tubes; *d*, a normal secondary tube which meets *d'* below and extends above to *c*, the latter overlapping and extending down to meet *a*, which in turn has overlapped *b* and extended up to meet *c*. At *b*—*d* there are *three* series of tubes between the primary series. Both *Chara fragilis* and *Ch. gymnopus* are, as a rule, regularly triplostichous; the former as regards the stem only, the latter both in stem and leaf.

Chara coronata, Ziz.—A description of the various forms of this species has been given recently in the *American Naturalist*, and it is unnecessary to reproduce it here. The cortex-cells of the basilar node of the leaf are rudimentary and the stems are entirely devoid of any cortex development. Plate XVI, illustrating one of the American varieties of this species, has been used in the *American Naturalist*.

CHARA INCONNEXA, *n. sp.*-Humilis, 3-4 cm. in alt. Caulis inermis, inferne ecorticatus, superne imperfecte corticatus cellularum seriebus cum numero foliorum congruentibus disjuncts. Folia verticilli 7—8, uno vel duobus ex articulis, foliola et fructiificationem gerentibus, partim ecorticatis, partim haplostiche disjunctis corticatis, partim diplostiche corticatis; segmentis ultimis elongatis, 1—2-articulatis, cellula terminali mucronem formante; corona stipularis e duplici cellularum serie, minima, inconspicua. Foliola plerumque unilateralia, posteriora saepe evoluta, anteriora sporangio breviora, non inflata. Sprorangium 8—10-striatum, 1 mm. long., coronula brevi truncata; nucleo 600μ longo.

This exceedingly interesting plant was collected in Iowa by Prof. C. E. Bessey. The lower portion of the stem is quite naked, and translucent like *Nitella*; the lower verticils consist of long Nitella-like leaves which bear no nodes or bracts and have generally two articulations, the termmal segment forming a short mucronate tip. These leaves seem to me to have no stipules, though I have not been able to examine fresh specimens. The lowest fertile leaves are always entirely naked, and in these verticils are found a few rudimentary leaves without nodes or bracts. In the upper part of the stem the internodes of the latter become corticated in the primitive manner described and illustrated in the figure. The character of the cortication seems to be quite like that of *Ch. imperfecta*, A. Br. *Ch. dissoluta* A. Br., differs in a partial development of the lateral cells of the node of the cortex, so that the space between the primary cells of the cortex is filled at *intervals*, though spaces are left between the nodes. *Ch. imperfecta* is, however, dioecious, and has quite long bracts. *Ch. dissoluta*, to which this plant seems most nearly allied, differs in the more numerous nodes of the leaves, the larger and more striated nucleus, etc.

The upper leaves of this plant vary greatly in the same verticils; two nodes are commonly found with bracts and fruit, the lowest internode having a perfect double cortex, the upper an imperfect, disconnected cortex, like the stem, the leaf above being entirely ecorticated and quite long. Some leaves have two fertile nodes, with only the lowest internode corticated in the disconnected, imperfect manner characteristic of this plant; while other leaves (generally but one or two in a verticil) one entirely barren of fruit, bract, or node, and have one or two simple articulations merely. Frequently, in the upper part of the stem, the posterior bracts are quite plainly developed, but much smaller than the anterior.

The plant is small and very dark green; the stems are clothed with the long straight leaves and are rigid with incrustation.

Chara crinita, Wallr. (Ann. Bot., 1815); *Ch. horridula*, Dethard-ing, in herb., 1809; *Ch. canescens*, Lois., Notice, 1810 ("Description imperfect," A. Braun); *Ch. muricata*, Hartmann, Skan. Flora, 1843; *Ch. condensata* et vars. *subflexilis* et *erythrella*, Wallm., 1854; *Ch. Karelini*, Lessing, Novit. Fl. Ross. in Linn., 1834; *Ch. erythraea*, Hering, in herb. Schimper; *Ch. dioica* et *Ch. sphagnoides*, Griffith, posth. papers.

Stem low, mostly simple or sparingly branched; cortical cells large, equalling the number of the leaves, completely encircling the stem ; the nodes of the cortex numerous, armed with spines usually three from each node, of about equal length, as long as the diameter of the stem ; the spines so numerous that the stem is completely hidden by them. *Stipules* double, directed upward and downward, two at the base of each leaf, the upper longer than the lower, as large as the spines, about as long as the first internode of the leaves. *Leaves* 8—10, usually 9, in a verticil, short, somewhat incurved ; internodes 4—7, usually 5, corticated like the stem, haplostichous, except the terminal segment, which is naked and simple, rarely articulated, and with the whorl of bracts of the last node, which are nearly as long, forming a terminal tuft. *Bracts* verticillate, equally developed all around the node, usually much longer than the sporangium, except three very short extra bracts subtending the sporangium, which seem to stand in the place of the antheridium, sometimes the middle one of these three "bracteoles" is elongated to nearly the length of the sporangium. *Sporangia* oblong-oval with 15–16 whorls on one side, coronula somewhat connivent (in American forms) rather short. Nucleus black, with 12 to 15 sharp angles on one side; in one form (*pachysperma*) broadly oval, in another (*leptosperma*) narrowly oblong. Antheridia very rarely seen ; the plant propagating itself by parthenogenesis. Dioecious.

I have considered the American plant a distinct variety, on account of its large seeds (nuclei 620 μ long ; in the European forms from 350 to 560 μ long) ; indeed, it seems to occupy a position nearer the following species (*Ch. evoluta*) than the European forms do.

The larger form (*pachysperma*) was gathered in 1860 by the writer on the shore of Great Pond, Montauk Point, Long Island. The pond at that time was fresh, or slightly brackish from the occasional breaking of salt water over the bar which separated it from the sea. Since then an inlet has opened and the pond has become nearly as salt as the sea, and though searched for repeatedly the plant has not been found there since. *Ch. aspera*, then found in company with *Ch. crinita* (as it frequently is), has disappeared also from that pond, though it may still be found in Fort Pond, a few miles distant, associated with *Ch. delicatula*, Ag. Forma *leptosperma* has been found at Polpis, Nantucket, by Mrs. Maria L. Owen. In the brackish lakes of Western Canada Prof. Macoun gathered, along with *Ch. evoluta*, some plants which approach very closely to *Ch. crinita.* They seem to be dioecious (no antheridia could be discovered), and to lack the small bracteoles in front of the sporangia, and they have large nuclei.

Prof. Nordstedt writes that *Ch. crinita* exhibits, in rare specimens, some tendency to the development of secondary cortex-tubes.

CHARA EVOLUTA, Allen (*in lit. ad* Prof. Nordstedt, 1881).—*Euchara*, *diplostephana*, *haplosticha* (vel *sub-diplosticha*), *monica.*

Humilis, 1—15 centimm. alt. Caulis aculeolis numerosis armatus, haplostiche *vel sub-diplostiche* corticatus ; aculeolis binis fasciculatis, caulis diametrum aequantibus. Folia verticilli 9—10, plerumque 9, haplostiche corticata ; articulis 4—5 (saepissime 5) corticatis, ultimo nudo bi-cellulari; articulis fructificationem gerentibus 3—4. Foliola omnium geniculorum evoluta, verticillata, sporangio longiora, exceptis duobus brevioribus antheridia lateralibsu, postica vix breviora. Corona stipularis sursum et deorsum evoluta, cellulis elongatis, seriei superioris articulum foliorum infimum aequantibus. Sporangium 11—12-striatum; coronula brevi, sub-connivente; nucleo atro, oblongo, 660μ long., 375—410μ lat., striis a latere inconspicuis (leiopyrena) 9—10.

This very interesting *Chara* was collected by Prof. Macoun of the Canadian Pacific Railway Survey, in July, 1879, in the *brackish* water of the Red-deer Lakes and in ponds west of the Saskatchawan.

From *Ch. crinita*, Wallr., it differs in being monoecious, and in the character of the cortex; but its general habit is exactly like that of *Ch. crinita*, Wallr., indeed among the specimens sent by Prof. Macoun are found a few, apparently dioecious, which I am unable to distinguish in any way from that species.

In *Ch. crinita* a node of the cortex develops a spine from each of the three external cells, so that the spines are fasciculated *in threes.* In this species but two of the cells develop spines, the central cell a long spine and one lateral cell a short one, while the other lateral cell remains undeveloped, or protrudes in the form of a small "button," (Fig. 2, *a*) or elongates somewhat, partially forming a secondary cortex-tube. A section of one of these partially developed tubes is shown in Fig. 3, *a*. Another feature of this plant exhibits its close relationship to *Ch. crinita*, namely, the smaller bracts on each side of the antheridium. In *Ch. crinita* three small bracts stand in front of the sporangium, the central one of which seems to occupy the place of the antheridium; in this place the antheridium occupies just the place of the central bract. *Chara crinita*, developing an antheridium instead of the central bract in front of the sporangium, and a secondary cortex-tube in place of a lateral cortex-spine, would nearly represent *Ch. evoluta.*

Another fact of significance is the discovery of an almost identical and similarly intermediate species in Central Asia. Prof. Nordstedt, in a recent letter to the writer, says: "I have discovered (in Braun's MS.) under *Ch. contraria* some remarks by Braun concerning *Ch. Altaica*, Br., ined. This species seems to stand *very* near your *Ch. evoluta.* Braun writes: 'This seems to me most nearly related to *Ch. crinita*, from which it is clearly different in being monoecious. The cortication of the leaves is like *Ch. crinita*, namely, above and below each bract only one cortex-cell, but under the antheridium there seem to be but two cells. On the stem, the cortex is very remarkable; at times the secondary cells are entirely wanting, at times there is one, at others there are two, but all are never developed, as a section proves. In this respect *Ch. Altaica* varies between the type of *Ch. crinita* and *contraria*, and *Ch. strigosa* and *aspera*; the cells are all very thin as in *crinita*, while in *strigosa* they are thick. The dorsal bracts of the leaf-nodes are elongated, and all the bracts connivent, also a peculiarity of *Ch. crinita*. *Ch. crinita* has, but rarely, traces of intermediate cortex-tubes.'"

From this description it would seem that the Asiatic species had developed slightly farther than the American.

The cortication of the leaf of *Ch evoluta* presents no marked variations from that of *Ch. crinita.* In the latter species there is a regular haplostichous cortication; Even the three small bracteoles have a cortex-tube for each, though often irregularly developed in the lowest node of the leaf, the centre bracteole may send a tube to the base of the leaf and the lateral ones be imperfectly developed; or the lateral bracteoles may send down a tube while the central bracteole may be imperfectly developed between them.

In *Ch. evoluta* the development is also irregular ; most frequently in the lowest node of the leaf three tubes are sent down, one from the base of the antheridium and one from each lateral bracteole; but the lateral tubes are usually small and often abortive (as in Fig. 5, *c*) in the upper node. The terminal segment of the leaf is not always two-celled, but sometimes one-celled and not longer than the surrounding bracts.

CHARA EXCELSA, *n. sp.*—*Euchara, diplostephana, perfecta, diplosticha, monoica.*

Humilis, statura et habitu *Ch. contrariam* aemulans. Caulis aculeolis sparsis armatus, diplostiche corticatus, seriebus cellullularum primariis prominulis. Folia verticilli 7–8, plerumque 8, articulis 5–6, fructificationem gerentibus 2–3 ; segmento ultimo nudo, bicellulari, saepe elongato ; foliis diplostiche corticatis. Foliola omnium geniculorum evoluta, verticillata sporangio longiora, postica vix breviora. Corona stipularis sursum et deorsum valde sed inequaliter evoluta. Sporangium 16–18-striatum, coronula brevi obtusa ; collo sporangii elongato. Nucleus ater, ovalis, 15–16-striatus, striis sub-prominulis, 750–800 μ longus.

This plant has the general appearance of *Ch. evoluta* and *crinita*, but is less spinescent. The cortex is almost regularly diplostichous, the primary series being much more prominent. Now and then the secondary series of cells extend past each other, and even additional tubes are developed, as in *Ch. aspera*, so that a section of the stem does not show just twice as many cells as there are leaves in the verticil. The spines of the stem are exceedingly variable in length, sometimes more than double the diameter of the stem, sometimes appearing as simple papillae. The stipules are also very irregular in size, some being more than double the length of others, the longest equalling the lowest node of the leaf. The leaves are regularly corticated in two series, and the terminal, naked segment, even in maturer plants, is often much elongated and two-celled. The bracts are verticillate, much longer than the sporangia, and present the general aspect of those of *Ch. crinita* and *evoluta.* The form of the sporangium is quite peculiar in the elongated neck, with short, round, thick cells a the top.

This species was collected in Canandaigua Lake, in August, 1881.

Chara aspera, (Dethard.) Willd.—*Sub-triplosticha, dioica.*—"Usually below medium size and correspondingly slender. Cortex of the stem imcompletely triplostichous, for the cells of the secondary series overlap and unite obliquely; the primary series often somewhat more prominent. (In our American specimens the cortex is extremely irregular, as may be seen by referring to the figures, which are exactly true to nature). Spines single, very variable in number and length, sometimes slender and sharp-pointed, sometimes short and very blunt. Stipules usually quite large but variable (in var. *Macounii,* Allen). Leaves 6 to 11 (usually 8) in a verticil, consisting of 3 to 7 (usually 6) corticated internodes and a naked tip, sometimes two-celled. Bracts on all the nodes; on the upper sterile nodes shorter, often inconspicuous; on the fertile nodes of the female plants there are usually 3 shorter, posterior, and (including the main bract, in place of the antheridium) 5 longer anterior bracts; of these the main bract is sometimes shorter, sometimes longer than the others. On the male plant the bracts are in general shorter than on the female, usually only two long anterior bracts, by the side of the antheridium. Sporangium oblong, with a short, broad, truncated coronula. Nucleus black, with inconspicuous angles, 440–500 μ long; striae on one side of the sporangium 14–16, on the nucleus 13–14. On the subterranean parts of the plant, small globular bulblets."

"Very variable in size and vigor, but usually with very slender stems, and slender leaves, mostly straight and rigidly spreading, rarely curved outwardly or inwardly. Color a clear green, light or dark, usually grayish with incrustation when old; in salt water more vigorous, yellowish or browish green and but slightly incrusted. The length of the leaves varies greatly, but very long leaves are unknown, while there are short-leaved forms (forma *brachyphylla*). The bracts are sometimes much longer than the sporangia, sometimes of equal length or even somewhat shorter; also the spines, always slender and straight, are often several times longer than the diameter of the stem, equal to it or shorter, rarely so short as to be almost unnoticed (forma *sub-inermis*). In young plants the terminal naked segments of the leaves may be greatly elongated (*Ch. fallax,* Ag.) On all forms, but most frequently on those growing in fresh or brackish water, are found chalky-white, globular tubers, which are situated on the nodes *of the rootlets,* seldom on the subterranean, defoliated and decorticated nodes of the stem; these are sometimes single, sometimes in groups of 2 to 5 and are nothing else than modified rootlets, formed of a single cell, filled with starch granules. Sometimes an ordinary filiform rootlet bears at its tip one, or even a whole bunch of such tubers. While the upper part of the plant dies in winter, these rootlets survive and give rise to new shoots, from the upper extremity of the tuber, or from a root-node on which the tuber is borne. Male and female plants are equally common and are found together." (A. Braun.)

The above comprehensive description, by Prof. Braun, embraces a great variety of forms from different countries. The forms of true *Ch. aspera* hitherto found in America are from New Mexico (Wright, 1857, No. 561); Long Island (Allen, 1860–1881) and Canada (Prof. Macoun, Canadian Pacific R. R. Survey, 1879–1880; brackish ponds west of Saskatchewan, etc.) All of these collections belong to the long-bracted and long-spined form, except the following marked variety, which I had ventured to consider a distinct species:

Var. MACOUNII, (*Ch. Macounii,* Allen *in litt.*)—Caulis aculeolis sparsis, inconspicuis, sub-inflatis obtusis armatus. Folia verticilli 6–8, plerumque 8; articulis 8, internodiis elongatis; sinistro torta.

Sporangium 10–12-striatum, coronula connivente, nucleo 8–9-striato. Foliola anteriora 3, sporangio multo breviora, posteriora inconspicua. Stipulae minutae. Nucleus niger, 450–475μ longus. Antheridium 550μ diametro.

The striking peculiarities of this variety are the torsion of the leaves (to the left, upward) ; the minute blunt spines ; small stipules and very short bracts ; the connivent cells of the coronula; and the small nucleus with fewer angles. All these differences would readily serve to distinguish this form as a distinct species, were it not for the fact that the *aspera* group is already large and its individuals difficult to distinguish. Doubtless they all have a common origin, and the variations are such as differences of climate, water, etc., determine. I have not found any bulbs on the specimens from Prof. Macoun, nor indeed, were any found on his *Ch. aspera*, nor did I succeed in collecting them on Long Island. The plants in this country seem to be in fruit in mid-summer. Our female plants seem to be longer leaved with more open verticils; and the male plants have, for the most part, shorter incurved leaves with one less node. The variety *Macounii* differs but little from *Ch. fragifera*, Dur., which is dioecious, has small bracts and stipules and long and slender twisted leaves; but the cortex is *perfectly* triplostichous. A long-leaved form of *Ch. fragilis*, Desv., sometimes has twisted leaves (forma *streptophylla*=*Ch. Hedwigii*, Ag.)

Chara fragilis, Desv., (*Ch. vulgaris*, L., in part).—*Triplosticha, monoica*.—"Medium size, relatively slender and rather rigid. Stem completely triplostichous and *symmetrically corticated*, *smooth*. Leaves in a whorl, 6–9, usually 7–8, for the most part slender and rigid, with 5–8 corticated segments and a very short tip of 1–2 naked cells. Stipules commonly very small, consisting of two series of small papillae, the cells of the upper row larger, those of the lower smaller and only partially developed. Bracts on the dorsum of the leaf obsolete ; on the upper sterile nodes all are often undeveloped ; the anterior bracts of a fertile node, usually 4 in number, including the prebracteoles, are sometimes shorter, sometimes equal to, sometimes longer than the fruit, and the two anterior (prebracteoles) are always the longer pair. Antheridia and sporangia single. Fruit oval or elongated, larger than *foetida* and *aspera*. Coronula elongated, with a conical, connivent or erect, rarely slightly divergent, tip. Incrustation thin. Nucleus black, elongated, with sharp angles and sharp spines, 550–660μ long. Striae on one side of the sporangium 15–16, on the nucleus 13–14. Usually of a fine green color, often a dark lake-green, always somewhat incrusted, when more incrusted grayish-green, and when dry whitish-gray (*Ch. hirta*, Meyen). The incrusted forms are very brittle. On the leaves of the sterile verticils there are scarcely any bracts. In deep water the species is perennial, living by means of sprouts from the lower nodes of the stem ; in drier places, annual. Very variable in size, length and thickness of leaf (forma *longifolia* et *brevifolia*, *tenuifolia* et *crassifolia*) as well as the length of the bracts, which has given rise to numerous untenable species." (A. Braun.)

This species, like *Ch. foetida*, A. Br., is found all over the world, but rarely in salt water. In the Uhited States it seems to be the most common species, being reported everywhere. It grows to a considerable length, with long slender leaves, in running water, or becomes very small and compact in still ponds. Multicellular tubers are formed on the lowest nodes.

Specimens have been found as follows: Maine, Prof. O. D. Allen. Vermont, at Charlotte (forma *microptila*), Mr. Pringle ; in Willoughby Lake (*tenuior longifolia*), Messrs. Horsford and Faxon ; at Ferrisburgh, Mr. Faxon. Massachusetts, at Boxford, Messrs. Faxon and T. F. Allen ; at Natick and Cambridge, Mr. Faxon ; at other places by Rev. Mr. Morong. Connecticut, at New Haven, Prof. O. D. Allen ; in Litchfield County quite common, T. F. Allen. New York, at Albany, Mr. Peck; at Penn Yan (forma *macroptila* var. *barbata*) ; in the lakes of Western New York, especially in Hemlock and Honeoye Lakes, and common in the lakes in the Adirondacks, T. F . Allen. Illinois (forma *longifolia major*, var. *Hedwigii*), Dr. J. Schenck. Iowa, J. C. Arthur and Prof. Bessey. California, Dr. A. Kellogg (forma *macroptila*). Yellowstone Park, in the hot Geyser Springs, *temperature* 100° *F.*, finely in fruit, but with only two elongated bracts, the lateral bracts very minute, herb. Gray, collected during Hayden's Survey.

(*Ch. delicatula*, Ag., by some considered a variety of *Ch. fragilis*, grows in Fort Pond, Montauk Point, Long Island. It is incompletely triplostichous; the stem is armed with small spines; the stipules are well developed; and the bracts are verticillate, but the dorsal ones small. Intermediate forms are known between this species and the typical *fragilis.*)

Description of Plate xvii, *Ch. inconnexa.*- A represents the plant, natural size. Fig. 1, a lower sterile verticil. Fig. 2, a higher verticil with naked leaves and with one node fertile, one quite sterile, and the stem corticated with a disconnected series of primary, node-bearing cortex-tubes. Fig. 3, an upper verticil, showing three (of the seven) leaves, one with a single fertile node, with the lowest internode corticated like the stem ; one with two fertile nodes, the lower of which has a perfect double cortex, the upper an imperfect cortex, and one sterile leaf without any node whatever. Fig. 4, a section of the stem showing the relation of the cortex-tubes to each other. Fig. 5, the terminal articulation of a leaf with its short mucronate cell. All the figures are magnified 100 diameters.

Explanation of Plate xviii, *Ch. crinita.*—A represents the normal size of the plant. Fig. 1, a portion of the stem with triple spines (less numerous than in nature, when they completely hide the stem); large double stipules equalling the lowest joint of the leaves; the long, verticillate bracts; the short coronula of the sporangium; and, at *a*, the three bracteoles subtending the sprorangium. (The male plant I have never seen.) Fig. 2, terminal nodes of a leaf, showing the one-celled, naked terminal, surrounded by long bracts. Fig. 3, a section of the stem. Fig. 4, a nucleus from Montauk Point (forma *pachysperma*). Fig. 5, nucleus from Nantucket (forma *leptosperma*).

Explanation of Plate xix, *Ch. evoluta.*—A and B represent the natural size of the plant; B though small is perfectly mature, with full-sized sporangia. Fig. 1, the stem with double spines, double stipules and one leaf with three fertile, two sterile nodes and a two-celled, terminal, naked segment, magnified 30 diameters. Fig. 2, a portion of the stem, showing at *a*, *b*, and *c* the partial development of one cell of a cortex-node into a cortex-tube, magnified 30 diameters. Fig. 3, a section of the stem, showing at *a'* a section of one of the incompletely developed secondary cortex tubes. Fig. 4, the point of one of the bracts (or spines) magnified 120 diameters. Fig. 5, the anterior aspect of a leaf (the two lowest nodes) showing at *a*, *a*, the site of the antheridium ; at *b*, *b*, the central cortex-tube, in the lower node covering the whole segment but tapering below, in the upper node extending down to fill the gap above the sporangium ; at *c*, *c*, lateral tubes, in the lower node dilating below, in the upper, larger above, on the right and on the left nearly obsolete ; at *d*, *d*, regular tubes from the bract. The group of three tubes arises from *one bract-node* of the leaf. The exact development of cells at the base of this node is not known ; it seems to have some peculiarties which require investigation with fresh specimens. Figs. 6 and 7, nuclei with faint striae.

EXPLANATION OF PLATE XX, *Ch. excelsa.*—A, plant natural size. Fig. 1, stem and verticil, showing variable cortex-spines and stipules. Fig. 2, a section of the stem, showing slight deviation from a regular diplostichous type. Fig. 3, two nodes of a leaf, with verticillate bracts. Fig. 4, terminal node of leaf with an elongated, naked, two-celled tip. Fig. 5, tip of one of the bracts (magnified 250 diameters). Fig. 6, one of the mature sporangia, showing the elongated neck, and short, blunt cells of the coronula. Fig. 7 and 8, mature muclei, with 15—16 sub-acute angles. The figures (except Fig. 5) are magnified 35 diameters.

EXPLANATION OF PLATE XXI. *Ch. aspera.*—A, a male plant of the ordinary form (from Long Island), natural size. B, a female plant of var. *Macounii*, natural size. Figs. 1–3, from normal form (*macroptila*). Fig. 1, a portion of the stem, showing the irregular formation of the cortex, and the base of a verticil showing the large stipules. Fig. 2, portion of a leaf bearing sporangia, with long verticillate bracts ; coronula somewhat divergent. Fig. 3, portion of a leaf from the male plant. Figs. 4–6, from var. *Macounii.* Fig. 4, stem, verticil and portion of leaf of a female plant, showing small blunt spines, irregular cortex, minute stipules, minute bracts, connivent coronula and the torsion of the leaf. Fig. 5, part of leaf of male plant. Fig. 6, terminal node of a leaf (not always with a *two*-celled naked segment, but often only one-celled). Fig. 7, a cluster of bulblets from the rootlets of a European specimen. These consist of a simple sack filled with starch granules of varying size, the largest averaging 70 μ in diameter, the interstices between the larger granules being densely packed with smaller ones. Fig. 7, *a*, one granule magnified 100 diameters, showing a black cross with polarized light. Figures all magnified 40 diameters.

EXPLANATION OF PLATE XXII, *Ch. fragilis.*--A, plant natural size with bulblets at the underground nodes. B, a verticil and leaf magnified 25 diameters; 8 and 9, and 8*a* and 9*a* showing two terminals, the single-celled one more common. C, an enlarged bulb, and a section showing numerous cells filled with starch granules. D, a node beginning to deposit starch in the nodal cells. The starch seems to form in the extremities of the main tubes of the stem, in the base of the leaves and in the cells surrounding the base of each leaf, thus giving rise to a very complicated tuber. The thickening of the tuber around the base of the leaves is well shown in the magnified tuber. Fig. 10, a nucleus.

On the Development of the Root-stock of Dicentra cucullaria.

By JOSEPH SCHRENK.

(Plate XXIII.)

When we examine this plant in December or January, we find that many of the singular bulblets of which the bulk of its subterranean portion consists, begin to push forth buds from near their bases, on the inner side (toward the axis). At this time we find these buds in various stages of development: some are mere protrusions above the epidermis, others show plainly one or two rudimentary leaves surrounded by several scales or bracts (Plate XXIII, Figs. 1 and 3). The more advanced buds have an elongated axis beset with large membranaceous bracts, which, overlapping one another, envelop the axis. In the axils of these bracts there are found miniature bulblets, either singly or in clusters, shaped like the large ones from which the buds have started; only at their upper end we discover a rudimentary, but very plainly tripartite leaf-blade incurved toward the axis (Fig.

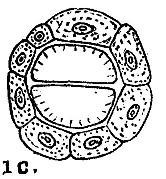


Fig. 1c.

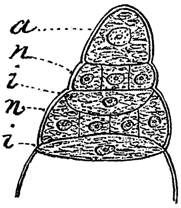


Fig. 1a.

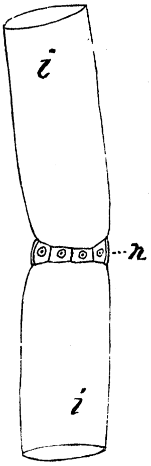


Fig. 1b.

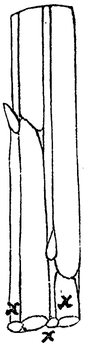


Fig. 6

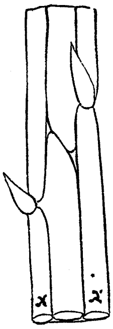
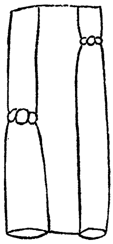


Fig. 7

Fig. 2



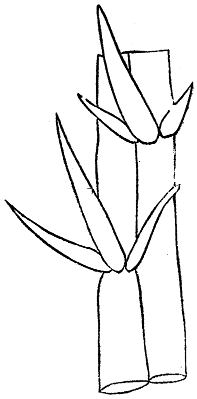


Fig. 3

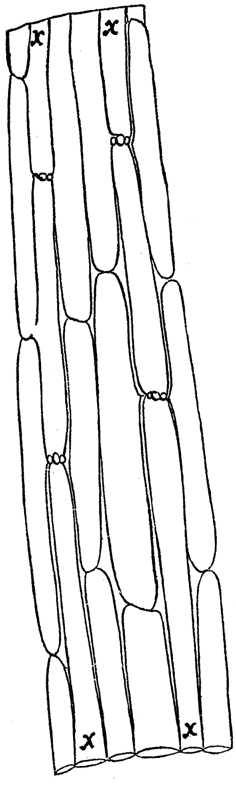


Fig. 8

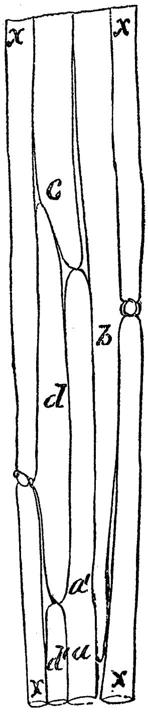


Fig. 8a.

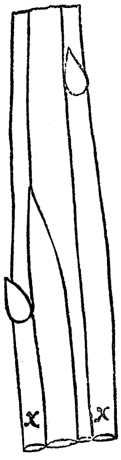


Fig. 7a.

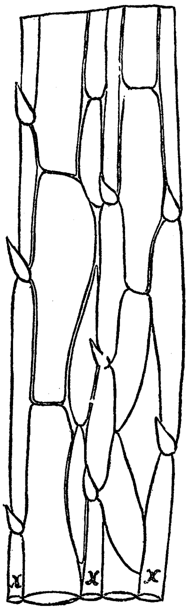


Fig. 7b.

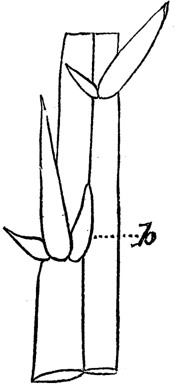


Fig. 4

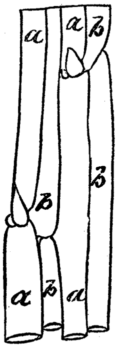
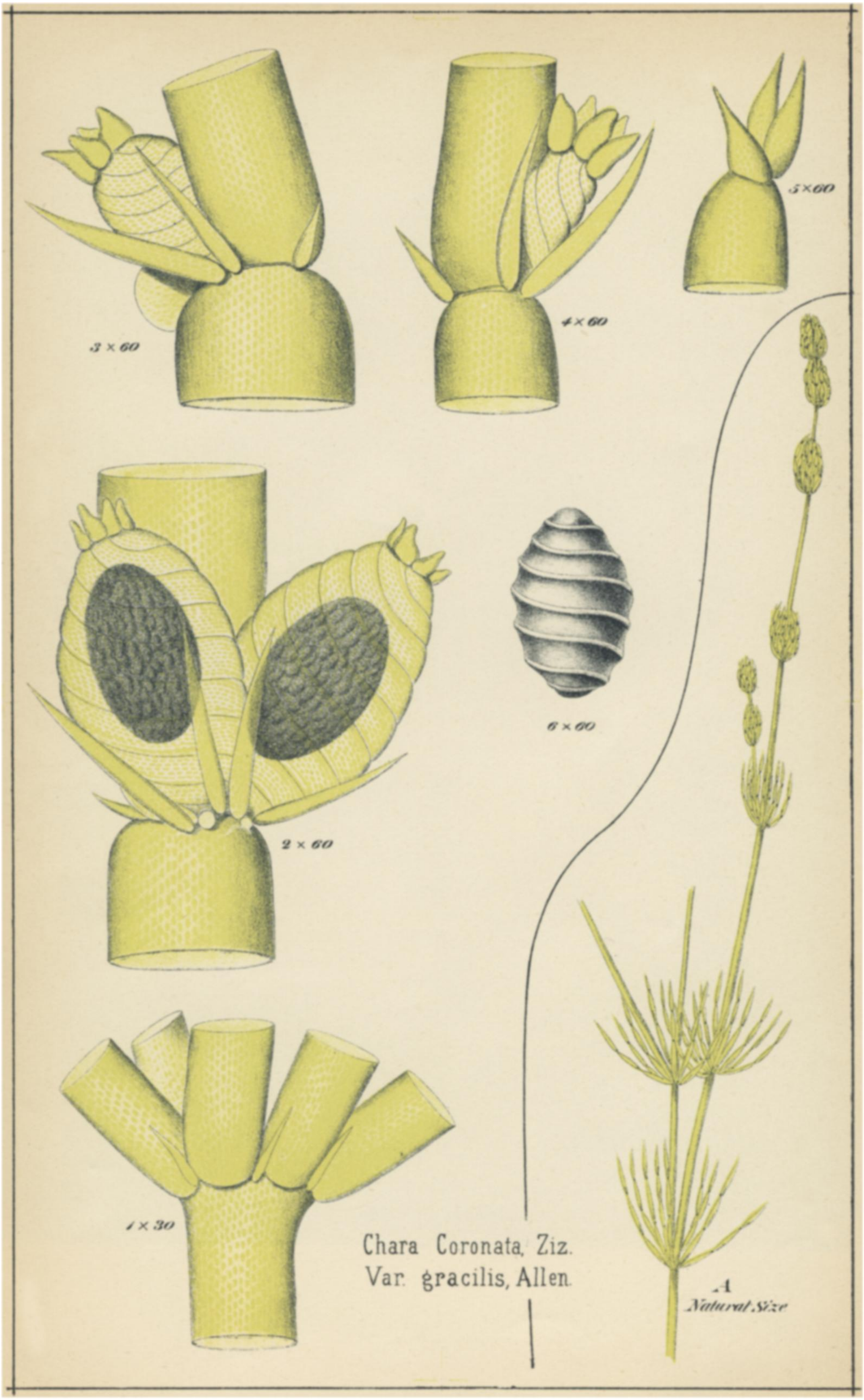


Fig. 5

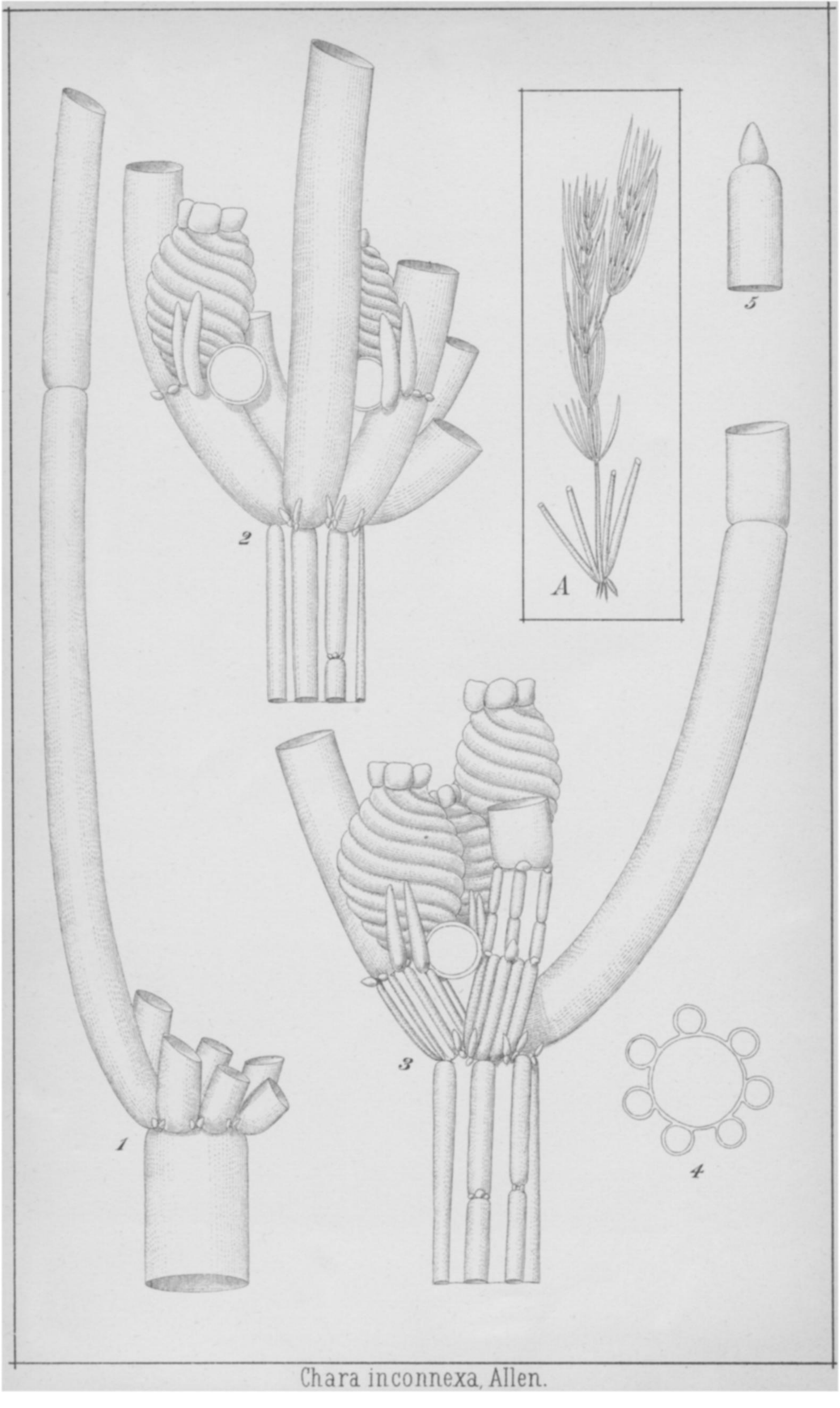
Development of the Cortex in Chara.

Bulletin Torrey Botanical Club Plate. XVI

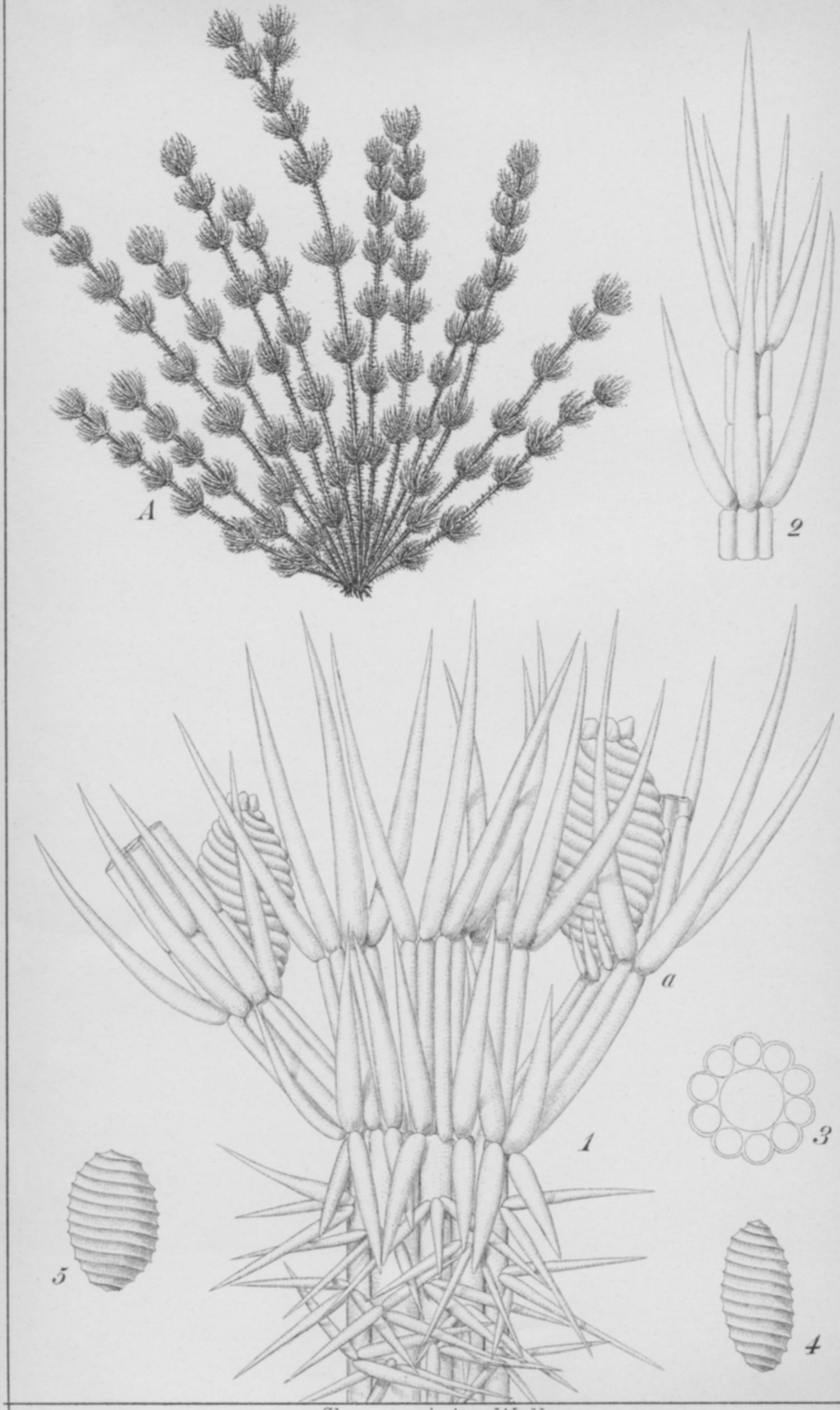


Chara Coronata, Ziz.
Var. gracilis, Allen.

Bulletin Torrey Botanical Club, Plate XVII.

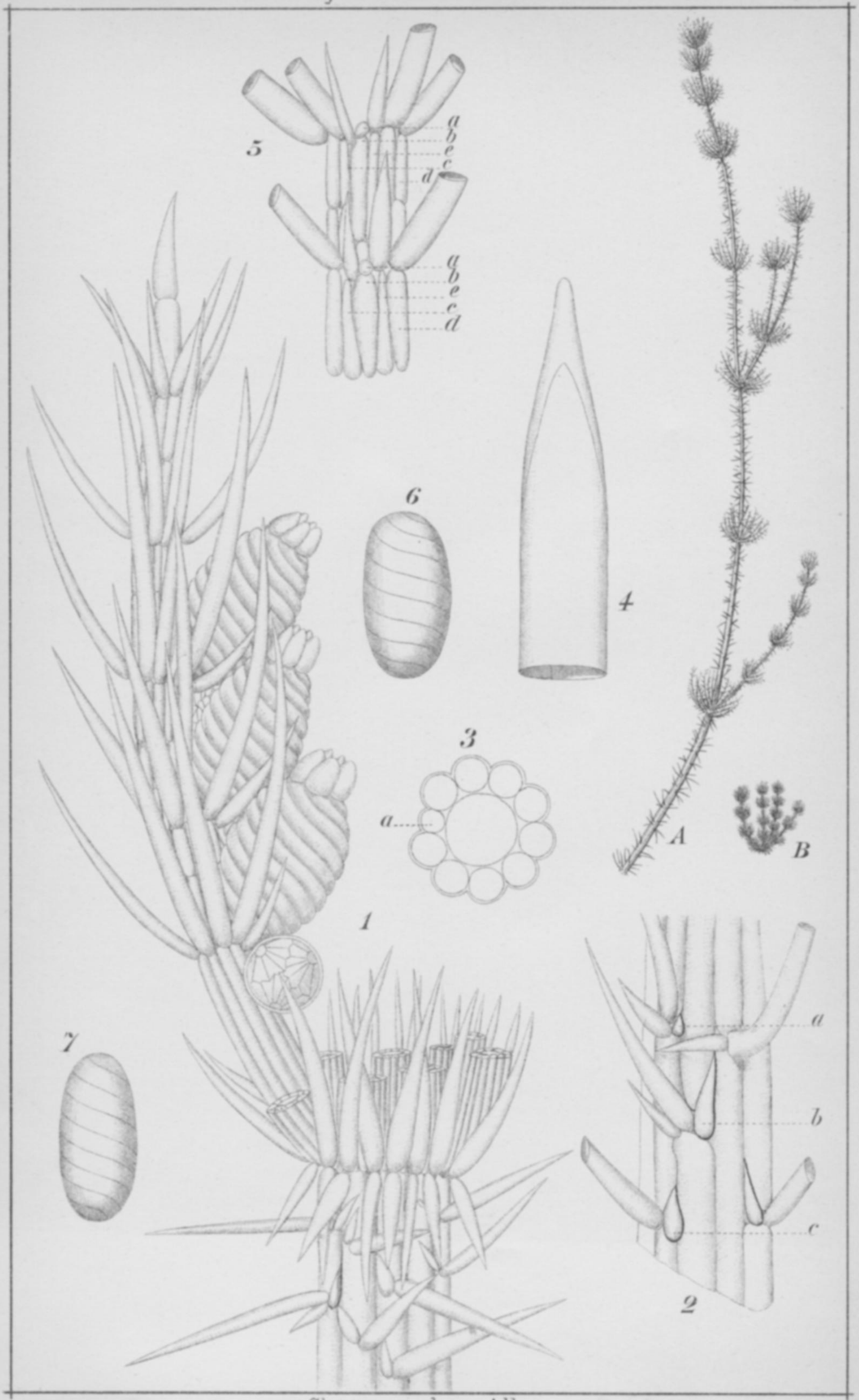


Chara inconnexa, Allen.



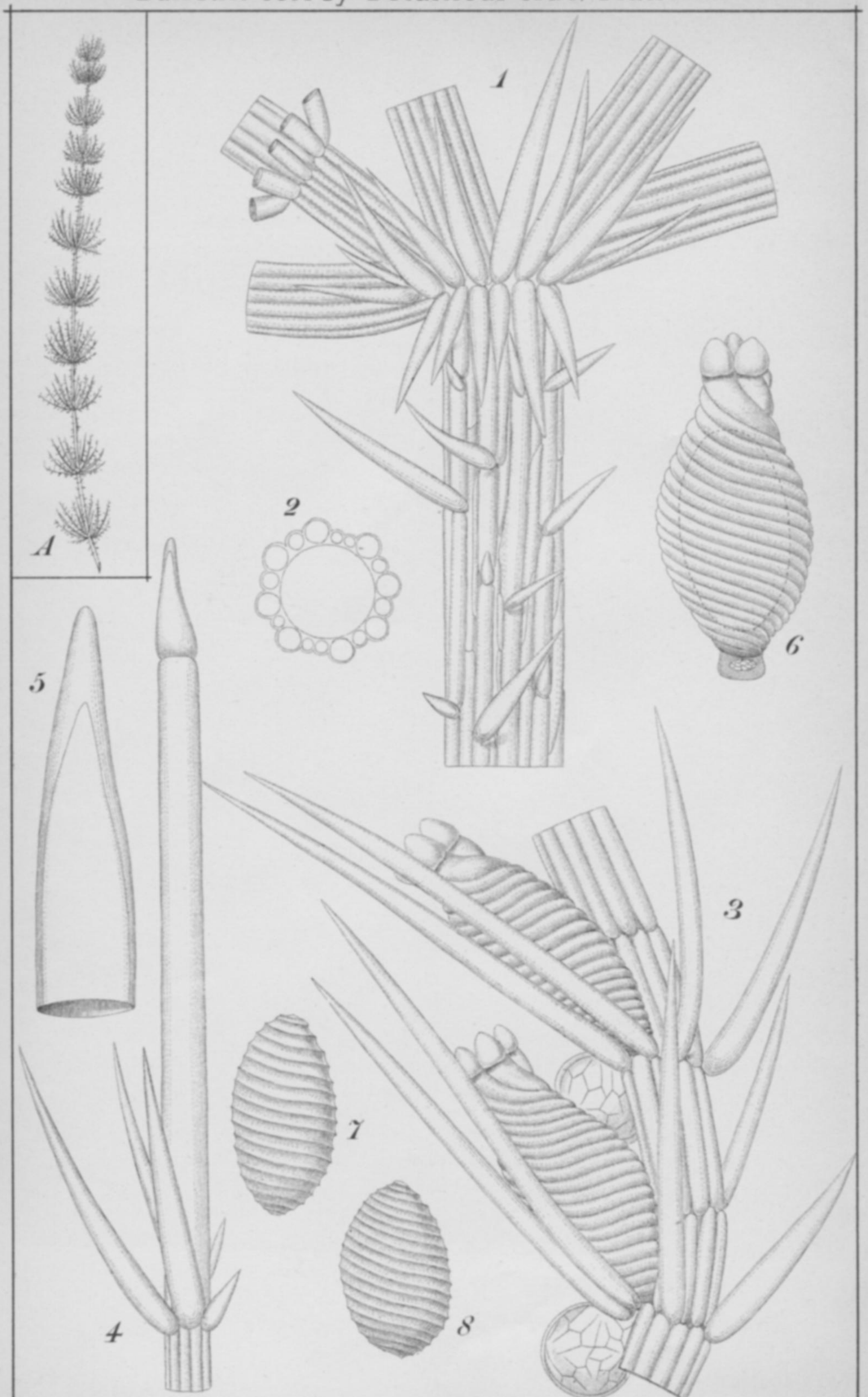
Chara crinita, Wallr.

Bulletin Torrey Botanical Club. Plate. XIX.

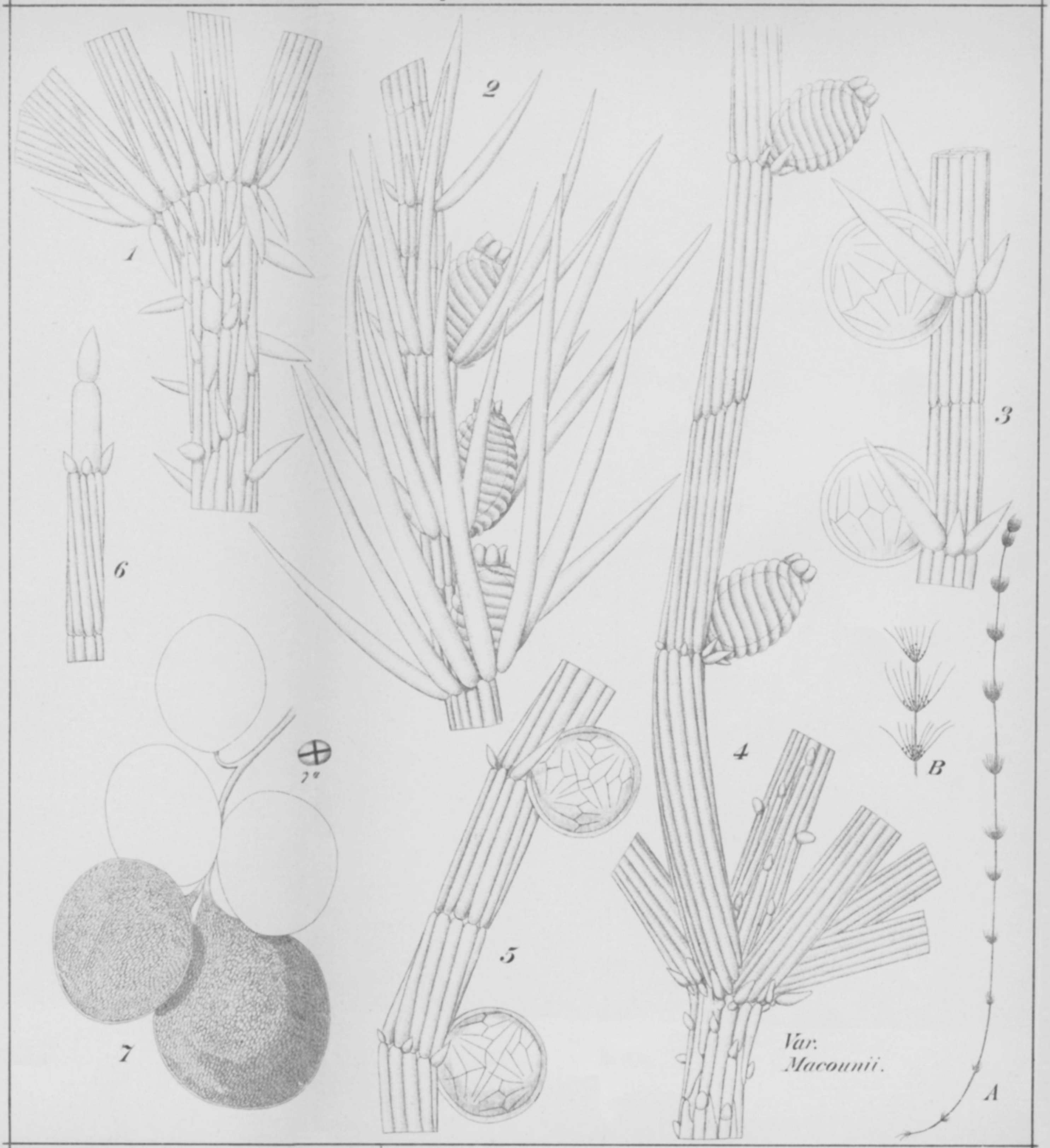


Chara evoluta, Allen.

Bulletin Torrey Botanical Club, Plate XX.

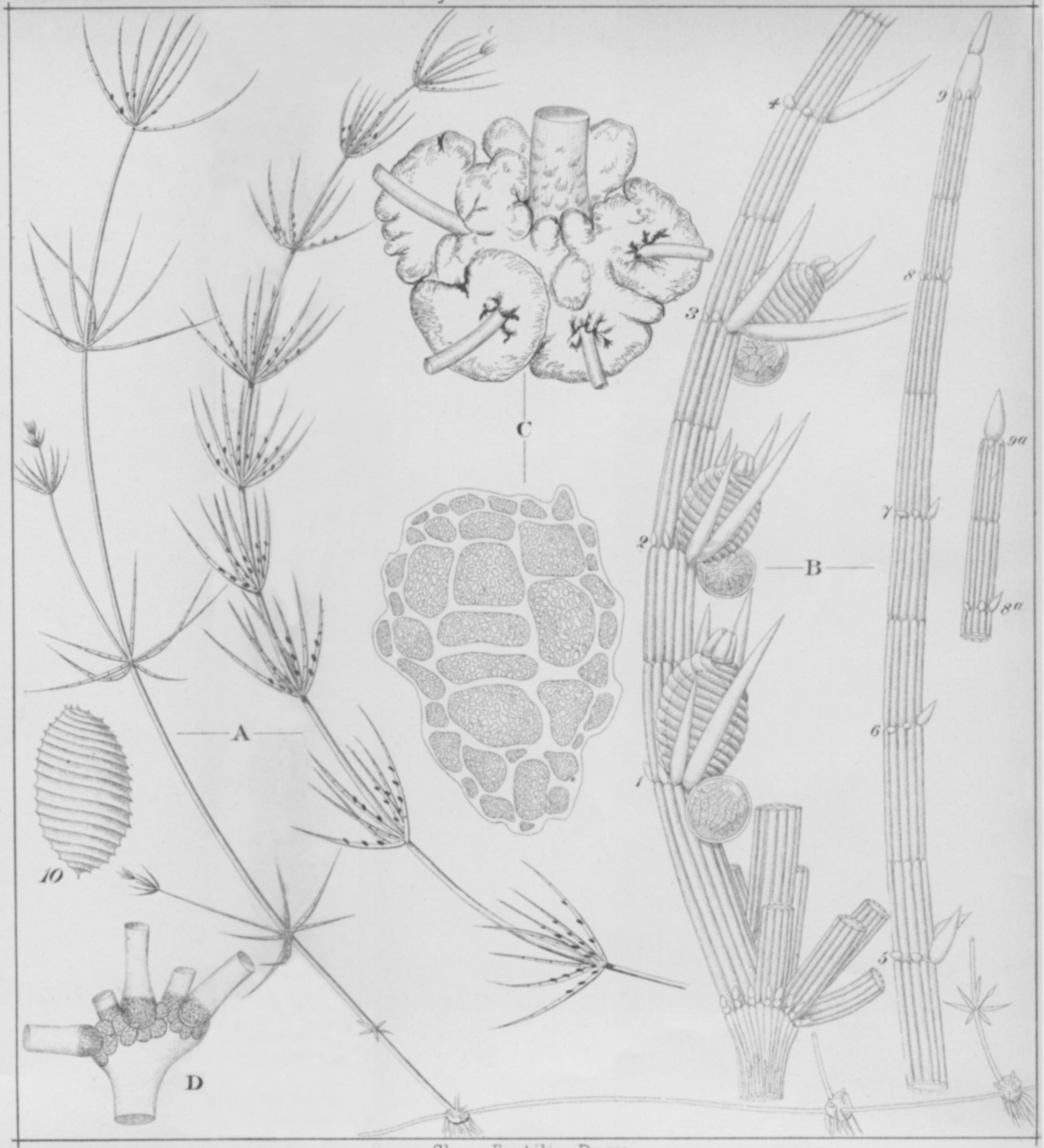


Chara excelsa, Allen.



Chara aspera, Willd.

Bulletin Torrey Botanical Club, Plate XXII.



Chara Fragilis, Desv.